

What is claimed is:

1. A method of thin film deposition for integrated circuit fabrication, comprising:
  - (a) providing a substrate;
  - (b) forming an organosilicate layer on the substrate; and
  - (c) treating the organosilicate layer with a plasma.
2. The method of claim 1 further, comprising:
  - (d) treating the substrate with a plasma prior to forming the organosilicate layer thereon.
3. The method of claim 2 wherein the plasmas of steps (b) and (d) are generated in a reaction chamber by applying an electric field to a gas mixture comprising oxygen ( $O_2$ ) and hydrogen ( $H_2$ ).
4. The method of claim 3 wherein the gas mixture further comprises one or more inert gases are selected from the group of helium (He), argon (Ar), nitrogen ( $N_2$ ), and combinations thereof.
5. The method of claim 3 wherein the electric field is a radio frequency (RF) power.
6. The method of claim 5 wherein the RF power is within a range of about 1 watt/cm<sup>2</sup> to about 100 watts/cm<sup>2</sup>.
7. The method of claim 3 wherein the reaction chamber is maintained at a pressure within a range of about 1 torr to about 10 torr.
8. The method of claim 3 wherein the plasma treatment is performed at a temperature within a range of about 50 °C to about 400 °C.

9. The method of claim 3 wherein the oxygen ( $O_2$ )/hydrogen ( $H_2$ ) gases are provided to the reaction chamber at flow rates within a range of about 500 sccm to about 5,000 sccm.

10. The method of claim 4 wherein the one or more inert gases are provided to the reaction chamber at flow rates within a range of about 500 sccm to about 5,000 sccm.

11. The method of claim 1 wherein the organosilicate layer is formed by:

- (e) positioning the substrate in a deposition chamber;
- (f) providing a gas mixture to the deposition chamber, wherein the gas mixture comprises a silicon source, a carbon source, and an oxygen source; and
- (g) applying an electric field to the gas mixture in the deposition chamber to form the carbon-containing silicate layer on the substrate.

12. The method of claim 11 wherein the silicon source and the carbon source comprise an organosilane compound having the general formula  $Si_aC_bH_cO_d$ , where a has a range between 1 and 2, b has a range between 1 and 10, c has a range between 6 and 30, and d has a range between 0 and 6.

13. The method of claim 12 wherein the organosilane compound is selected from the group of methylsilane ( $SiCH_3$ ), dimethylsilane ( $SiC_2H_6$ ), trimethylsilane ( $SiC_3H_{10}$ ), tetramethylsilane ( $SiC_4H_{12}$ ), methoxysilane ( $SiCH_3O$ ), dimethyldimethoxysilane ( $SiC_4H_{12}O_2$ ), diethyldiethoxysilane ( $SiC_6H_{18}O_2$ ), dimethyldiethoxysilane ( $SiC_6H_{16}O_2$ ), diethyldimethoxysilane ( $SiC_6H_{16}O_2$ ), hexamethyldisiloxane ( $Si_2C_6H_{18}O$ ), bis(methylsilano)methane ( $Si_2C_3H_{12}$ ), 1,2-bis(methylsilano)ethane ( $Si_2C_4H_{14}$ ), and combinations thereof.

14. The method of claim 11 wherein the oxygen source is selected from the group of nitrous oxide ( $N_2O$ ), oxygen ( $O_2$ ), ozone ( $O_3$ ), carbon monoxide (CO), carbon dioxide ( $CO_2$ ), and combinations thereof.

15. The method of claim 11 wherein the electric field applied to the gas mixture in the deposition chamber is a radio frequency (RF) power.

16. The method of claim 15 wherein the RF power is within a range of about 1 watt/cm<sup>2</sup> to about 500 watts/cm<sup>2</sup>.

17. The method of claim 11 wherein the deposition chamber is maintained at a pressure between about 1 torr to about 500 torr.

18. The method of claim 12 wherein the organosilane compound is provided to the deposition chamber at a flow rate in a range of about 50 sccm to about 1,000 sccm.

19. The method of claim 11 wherein the oxygen source is provided to the deposition chamber at a flow rate in a range of about 10 sccm to about 200 sccm.

20. The method of claim 12 wherein the ratio of the oxygen source to the organosilane compound is about 1:1 to about 1:5.

21. The method of claim 11 wherein the deposition chamber is maintained at a temperature between about 50 °C to about 500 °C.

22. The method of claim 11 wherein the gas mixture further comprises an inert gas.

23. The method of claim 22 wherein the inert gas is selected from the group of helium (He), argon (Ar), neon (Ne), xenon (Xe), and combinations thereof.

24. The method of claim 22 wherein the inert gas is provided to the deposition chamber at a flow rate in a range of about 10 sccm to about 1,000 sccm.

25. A computer storage medium containing a software routine that, when executed, causes a general purpose computer to control a deposition chamber using a layer deposition method, comprising:

- (a) providing a substrate;
- (b) forming an organosilicate layer on a substrate; and
- (c) treating the organosilicate layer with a plasma.

26. The computer storage medium of claim 25 further, comprising:

- (d) treating the substrate with a plasma prior to forming the organosilicate layer thereon.

27. The computer storage medium of claim 26 wherein the plasmas of step (b) and (d) are generated in a reaction chamber by applying an electric field to a gas mixture comprising oxygen ( $O_2$ ) and hydrogen ( $H_2$ ).

28. The computer storage medium of claim 27 wherein the gas mixture further comprises one or more inert gases are selected from the group of helium (He), argon (Ar), nitrogen ( $N_2$ ), and combinations thereof.

29. The computer storage medium of claim 27 wherein the electric field is a radio frequency (RF) power.

30. The computer storage medium of claim 29 wherein the RF power is within a range of about 1 watt/cm<sup>2</sup> to about 100 watts/cm<sup>2</sup>.

31. The computer storage medium of claim 27 wherein the reaction chamber is maintained at a pressure within a range of about 1 torr to about 10 torr.

32. The computer storage medium of claim 27 wherein the plasma

treatment step is performed at a temperature within a range of about 50 °C to about 400 °C.

33. The computer storage medium of claim 27 wherein the oxygen (O<sub>2</sub>)/hydrogen (H<sub>2</sub>) gases are provided to the reaction chamber at flow rates within a range of about 500 sccm to about 5,000 sccm.

34. The computer storage medium of claim 28 wherein the one or more inert gases are provided to the reaction chamber at a flow rate within a range of about 500 sccm to about 5,000 sccm.

35. The computer storage medium of claim 26 wherein the organosilicate layer is formed by:

- (e) positioning the substrate in a deposition chamber;
- (f) providing a gas mixture to the deposition chamber, wherein the gas mixture comprises a silicon source, a carbon source, and an oxygen source; and
- (g) applying an electric field to the gas mixture in the deposition chamber to form the organosilicate layer on the substrate.

36. The computer storage medium of claim 35 wherein the silicon source and the carbon source comprise an organosilane compound having the general formula Si<sub>a</sub>C<sub>b</sub>H<sub>c</sub>O<sub>d</sub>, where a has a range between 1 and 2, b has a range between 1 and 10, c has a range between 6 and 30, and d has a range between 0 and 6.

37. The computer storage medium of claim 36 wherein the organosilane compound is selected from the group of methylsilane (SiCH<sub>3</sub>), dimethylsilane (SiC<sub>2</sub>H<sub>6</sub>), trimethylsilane (SiC<sub>3</sub>H<sub>10</sub>), tetramethylsilane (SiC<sub>4</sub>H<sub>12</sub>), methoxysilane (SiCH<sub>3</sub>O), dimethyldimethoxysilane (SiC<sub>4</sub>H<sub>12</sub>O<sub>2</sub>), diethyldiethoxysilane (SiC<sub>8</sub>H<sub>18</sub>O<sub>2</sub>), dimethyldiethoxysilane (SiC<sub>6</sub>H<sub>16</sub>O<sub>2</sub>), diethyldimethoxysilane (SiC<sub>8</sub>H<sub>18</sub>O<sub>2</sub>), hexamethyldisiloxane (Si<sub>2</sub>C<sub>6</sub>H<sub>18</sub>O), bis(methylsilano)methane (Si<sub>2</sub>C<sub>3</sub>H<sub>12</sub>), 1,2-bis(methylsilano)ethane (Si<sub>2</sub>C<sub>4</sub>H<sub>14</sub>), and combinations thereof.

38. The computer storage medium of claim 35 wherein the oxygen source is selected from the group of nitrous oxide ( $N_2O$ ), oxygen ( $O_2$ ), ozone ( $O_3$ ), carbon monoxide ( $CO$ ), carbon dioxide ( $CO_2$ ), and combinations thereof.

39. The computer storage medium of claim 35 wherein the electric field applied to the gas mixture in the deposition chamber is a radio frequency (RF) power.

40. The computer storage medium of claim 39 wherein the RF power is within a range of about 1 watt/cm<sup>2</sup> to about 500 watts/cm<sup>2</sup>.

41. The computer storage medium of claim 35 wherein the deposition chamber is maintained at a pressure between about 1 torr to about 500 torr.

42. The computer storage medium of claim 36 wherein the organosilane compound is provided to the deposition chamber at a flow rate in a range of about 50 sccm to about 1,000 sccm.

43. The computer storage medium of claim 35 wherein the oxygen source is provided to the deposition chamber at a flow rate in a range of about 10 sccm to about 200 sccm.

44. The computer storage medium of claim 36 wherein the ratio of the oxygen source to the organosilane compound is about 1:1 to about 1:5.

45. The computer storage medium of claim 35 wherein the deposition chamber is maintained at a temperature between about 50 °C to about 500 °C.

46. The computer storage medium of claim 35 wherein the gas mixture further comprises an inert gas.

47. The computer storage medium of claim 46 wherein the inert gas is

selected from the group of helium (He), argon (Ar), neon (Ne), xenon (Xe), and combinations thereof.

48. The computer storage medium of claim 46 wherein the inert gas is provided to the deposition chamber at a flow rate in a range of about 10 sccm to about 1,000 sccm.

49. A method of fabricating a damascene structure, comprising:

- (a) forming a barrier layer on a substrate having a metal layer thereon;
- (b) forming a first organosilicate layer on the barrier layer;
- (c) treating the first organosilicate layer with a plasma;
- (d) forming a hardmask layer on the first organosilicate layer;
- (e) patterning the hardmask layer to define vias therein;
- (f) forming a second organosilicate layer on the patterned hardmask layer;
- (g) treating the second organosilicate layer with a plasma;
- (h) patterning the second organosilicate layer to define interconnects therein, wherein the interconnects are positioned over the vias defined in the hardmask layer;
- (i) etching the first organosilicate layer to form vias therethrough; and
- (j) filling the vias and interconnects with a conductive material.

50. The method of claim 49 further, comprising:

- (k) treating the substrate with a plasma prior to forming the first and second organosilicate layers of steps (b) and (f).

51. The method of claim 49 wherein the conductive material filling the vias and interconnects is selected from the group of copper (Cu), aluminum (Al), tungsten (W), and combinations thereof.

52. The method of claim 49 wherein the plasmas of either step (c) and (g)

are generated in a reaction chamber by applying an electric field to a gas mixture comprising oxygen (O<sub>2</sub>) and hydrogen (H<sub>2</sub>).

53. The method of claim 52 wherein the gas mixture further comprises one or more inert gases are selected from the group of helium (He), argon (Ar), nitrogen (N<sub>2</sub>), and combinations thereof.

54. The method of claim 52 wherein the electric field is a radio frequency (RF) power.

55. The method of claim 54 wherein the RF power is within a range of about 1 watt/cm<sup>2</sup> to about 100 watts/cm<sup>2</sup>.

56. The method of claim 52 wherein the reaction chamber is maintained at a pressure within a range of about 1 torr to about 10 torr.

57. The method of claim 52 wherein the plasma treatment is performed at a temperature within a range of about 50 °C to about 400 °C.

58. The method of claim 52 wherein the oxygen (O<sub>2</sub>)/hydrogen (H<sub>2</sub>) gases are provided to the reaction chamber at flow rates within a range of about 500 sccm to about 5,000 sccm.

59. The method of claim 53 wherein the one or more inert gases are provided to the reaction chamber at a flow rate within a range of about 500 sccm to about 5,000 sccm.

60. The method of claim 49 wherein the first and second organosilicate layers of either steps (b) or (f) is formed by:

positioning the substrate in a deposition chamber;

providing a gas mixture to the deposition chamber, wherein



the gas mixture comprises a silicon source, a carbon source, and an oxygen source; and

applying an electric field to the gas mixture in the deposition chamber to form the organosilicate layer on the substrate.

61. The method of claim 60 wherein the silicon source and the carbon source comprise an organosilane compound having the general formula  $\text{Si}_a\text{C}_b\text{H}_c\text{O}_d$ , where a has a range between 1 and 2, b has a range between 1 and 10, c has a range between 6 and 30, and d has a range between 0 and 6.

62. The method of claim 61 wherein the organosilane compound is selected from the group of methylsilane ( $\text{SiCH}_3$ ), dimethylsilane ( $\text{SiC}_2\text{H}_6$ ), trimethylsilane ( $\text{SiC}_3\text{H}_{10}$ ), tetramethylsilane ( $\text{SiC}_4\text{H}_{12}$ ), methoxysilane ( $\text{SiCH}_3\text{O}$ ), dimethyldimethoxysilane ( $\text{SiC}_4\text{H}_{12}\text{O}_2$ ), diethyldiethoxysilane ( $\text{SiC}_6\text{H}_{18}\text{O}_2$ ), dimethyldiethoxysilane ( $\text{SiC}_6\text{H}_{16}\text{O}_2$ ), diethyldimethoxysilane ( $\text{SiC}_6\text{H}_{16}\text{O}_2$ ), hexamethyldisiloxane ( $\text{Si}_2\text{C}_6\text{H}_{18}\text{O}$ ), bis(methylsilano)methane ( $\text{Si}_2\text{C}_3\text{H}_{12}$ ), 1,2-bis(methylsilano)ethane ( $\text{Si}_2\text{C}_4\text{H}_{14}$ ), and combinations thereof.

63. The method of claim 60 wherein the oxygen source is selected from the group of nitrous oxide ( $\text{N}_2\text{O}$ ), oxygen ( $\text{O}_2$ ), ozone ( $\text{O}_3$ ), carbon monoxide ( $\text{CO}$ ), carbon dioxide ( $\text{CO}_2$ ), and combinations thereof.

64. The method of claim 60 wherein the electric field applied to the gas mixture in the deposition chamber is a radio frequency (RF) power.

65. The method of claim 64 wherein the RF power is within a range of about 1 watt/cm<sup>2</sup> to about 500 watts/cm<sup>2</sup>.

66. The method of claim 60 wherein the deposition chamber is maintained at a pressure between about 1 torr to about 500 torr.

67. The method of claim 61 wherein the organosilane compound is

provided to the deposition chamber at a flow rate in a range of about 50 sccm to about 1,000 sccm.

68. The method of claim 60 wherein the oxygen source is provided to the deposition chamber at a flow rate in a range of about 10 sccm to about 200 sccm.

69. The method of claim 61 wherein the ratio of the oxygen source to the organosilane compound is about 1:1 to about 1:5.

70. The method of claim 60 wherein the deposition chamber is maintained at a temperature between about 50 °C to about 500 °C.

71. The method of claim 60 wherein the gas mixture further comprises an inert gas.

72. The method of claim 71 wherein the inert gas is selected from the group of helium (He), argon (Ar), neon (Ne), xenon (Xe), and combinations thereof.

73. The method of claim 71 wherein the inert gas is provided to the deposition chamber at a flow rate in a range of about 10 sccm to about 1,000 sccm.